CDF note 7925

$Br(B^0 \to D_s D^+)/Br(B^0 \to D^+\pi\pi\pi)$ $D_s \to \phi\pi(3\pi, K^*K)$, $D^+ \to K\pi\pi$ with $355pb^{-1}$ in Run II

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(Dated: January 19, 2006)

We conducted a study of the ratio of the branching fractions $\frac{Br(B^0 \to D_s^+ D^-)}{Br(B^0 \to D^- 3\pi)}$ where $D_s \to \phi\pi(K^*K, 3\pi)$ and $D^+ \to K\pi\pi$. This study is an update to the first observation at CDF and branching fraction measurement of $B^0 \to D_s^+ D^-$ covered by [1]. Major changes compare to the previous analysis:

- Added $110pb^{-1}$ more luminosity
- Improved handling of physics backgrounds
- More accurate combining of the data from several triggers
- $B^0 \to D_s^{+(*)} D^{-(*)}$measurements included

This analysis is a part of a wider branching fraction measurements program [1] [2]. It is one of the technical prerequisites for a more challenging measurement of $\frac{Br(B_s \to D_s^+ D_s^-)}{Br(B^0 \to D_s^+ D^-)}$ with the same decay channels for charm mesons.

Preliminary Results for Winter 2006 Conferences

I. DESCRIPTION

This note is an update to our first observation of $B^0 \to D_s^+ D^-$ at CDF [1]. We also treat this measurement as a technical prerequisite to a more challenging observation and measurement of $B_s \to D_s^+ D_s^-$.

$B_s \to D_s^+ D_s^-$ has a pure CP even final state and $B_s \to D_s^{(*)+} D_s^{(*)-}$ has a predominantly CP even final state. These modes are the major contributors to the phase-space difference between the even and the odd B_s decay channels. Measuring the total branching fraction of double charm B_s decays should give an estimate for $\frac{\Delta\Gamma}{\Gamma}$.

$B_s \to D_s^+ D_s^-$ measurement is difficult due to the small branching fractions of charm meson decays available for full hadronic reconstruction. Our estimate is that with the current data sample of $355 pb^{-1}$ we will be able to observe $B_s \to D_s^+ D_s^-$ only combining two hadronic trigger paths and several D_s decay modes.

To test our tools we use similar but more populated modes. To suppress systematics we study ratios of branching fractions. Several of them will give us a good handle to test and tune our techniques.

$$\frac{Br(B_s^0 \to D_s^+ 3\pi)}{Br(B^0 \to D^- 3\pi)}, \quad (D_s^+ \to \phi\pi(3\pi, K^* K), D^+ \to K\pi\pi) \tag{1}$$

$$\frac{Br(B^0 \to D_s^+ D^-)}{Br(B^0 \to D^- 3\pi)}, \quad (D_s^+ \to \phi\pi(3\pi, K^* K), D^+ \to K\pi\pi) \tag{2}$$

$$\frac{Br(B_s \to D_s^+ D_s^-)}{Br(B^0 \to D_s^+ D^-)}, \quad (D_s^+ \to \phi\pi(3\pi, K^* K), D^+ \to K\pi\pi) \tag{3}$$

All the listed decay modes have six tracks in the final state and share similar topology with two secondary resonances decaying into three tracks each. Using the same D_s and D^+ decay modes allows to optimize reconstruction and reduce systematics.

This setup provides a lot of possibilities for crosschecks and additional studies. The first ratio is measured in [2]. This note describes the measurement of the second ratio. The study of the third ratio will finish the sequence.

II. DETAILS

The analysis cuts were chosen by optimizing a yield of scaled signal Monte Carlo with respect to combinatorial background. The signal region was blinded for the procedure. The final cut values are summarized in tables I and II.

The fit function for every mode consist of three major parts.

- **Signal** - sharp resonant peak at B^0 or B_s mass with width defined by detector and reconstruction resolution.
- **Combinatorial background** - a smooth featureless background due to the accidental combinations of the tracks from underlying event happened to pass the analysis cuts.
- **Physics background** - a spiky background with a lot of features due to the incomplete or incorrect reconstruction of the decays similar to signal in mass, decay content and topology.

In this analysis a good part of the effort was spent to identify and estimate physics backgrounds. We were able to single out several decay modes providing a significant contribution to the background within the fit window. For these modes a dedicated Monte Carlo samples were generated to create fitting templates. The rest of the physics backgrounds were studied with the help of *"semi-generic"* Monte Carlo. For example to study physics backgrounds for $B^0 \to D^- 3\pi$, $D^- \to K^+\pi^-\pi^-$ a semi-generic Monte Carlo $B \to D^- X$ was generated. Here B stands for all the B-mesons, X - stands for "anything" and D^--meson is forced to decay to $K^+\pi^-\pi^-$.

Due to many physics backgrounds very complicated functions with tens of parameters were used to fit the data (figures 1, 2, 3 and 4). However most of the parameters were fixed within the templates - frozen shapes created to describe the major backgrounds. For each template only a single normalization parameter was left free in the final fit.

Most of the systematic uncertainties in this measurement are connected to Monte Carlo. Tables V and VI summarize the systematic errors for the measurements.

- B P_T **spectrum**. We computed the efficiency for the signal mode using B-mesons generated with the measured transverse momentum spectrum [3]. We also computed the efficiency using B-mesons generated with a spectrum reweighed to match the spectrum observed in this data. Comparing these two with the efficiency we got from the default Peterson model [4] we estimated the systematic error due to the effect.
- $B^0 \to D3\pi$ **composition**. This systematic uncertainty estimates the error due to the limited knowledge of the 3π resonant structure of the B_d meson decay. We had to tune our Monte Carlo decay file to make 3π invariant mass distribution agree with data. The tuning was based on our own study and `BaBar` results [5]. In the final version a_1 resonance is dominating (90%) in 3π system. The systematic uncertainty was estimated by changing 3π sub-resonance content and also by varying a_1 parameters such as mass, width and decay hypothesis.
- $D_s \to \pi\pi\pi$ **composition**. This systematic uncertainty estimates the error due to the limited knowledge of the 3π resonant structure of the D_s meson decay. The systematic was estimated by applying very extreme changes to D_s decay model and content. More subtle study could be done in the next iteration of the analysis.
- **Fit related** systematic uncertainty was estimated by
  - Changing fit range
  - Changing the fixed parameters of the templates within one sigma of our best knowledge
  - Allowing some of the parameters to float
- **Cut systematics** or systematic uncertainties due to placement of selection criteria arise from the remaining differences between data and Monte Carlo. We estimated it by scanning our selection cuts within wide regions and observing the changes in the measured values.

Using values of efficiencies and yields from table III along with branching fractions and ratios listed in the table VII we calculated the ratio of branching fractions for $B^0 \to\ D_s^+D^-$ with three different D_s decay modes separately. Branching fractions with respect to $D_s \to \phi\pi$ are taken from PDG 2004 [6]. PDG 2005 [7] only average the ratios with respect to $D_s \to KK\pi$ non-resonant following the most recent Dialitz study of $D_s \to KK\pi$ [8]. We are aware of a new measurement of $Br(D_s \to \phi\pi)$ [9]. We did not use it in this analysis waiting for PDG to include it into the average. For our dataset, we obtained:

$$\frac{Br(B^0 \to\ D_s^+D^-, D_s^+ \to \phi\pi)}{Br(B^0 \to\ D^-3\pi)} = 2.00 \pm 0.17(stat) \pm 0.45(BR_{\phi\pi^+}) \pm 0.13(syst)$$

$$\frac{Br(B^0 \to\ D_s^+D^-, D_s^+ \to K^*K)}{Br(B^0 \to\ D^-3\pi)} = 1.86 \pm 0.22(stat) \pm 0.41(BR_{\phi\pi^+}) \pm 0.18(BR) \pm 0.14(syst)$$

$$\frac{Br(B^0 \to\ D_s^+D^-, D_s^+ \to \pi\pi\pi)}{Br(B^0 \to\ D^-3\pi)} = 2.20 \pm 0.32(stat) \pm 0.49(BR_{\phi\pi^+}) \pm 0.28(BR) \pm 0.18(syst)$$

The branching fraction error due to $D_s \to \phi\pi$ is isolated into a common correlated part. The rest of the branching error is coming from the ratios of branching fractions listed in table VII.

Combining three $B^0 \to\ D_s^+D^-$modes for our data sample we obtained:

$$\frac{Br(B^0 \to\ D_s^+D^-)}{Br(B^0 \to\ D^-3\pi)} = 1.99 \pm 0.13(stat) \pm 0.44(Br_{\phi\pi}) \pm 0.08(Br) \pm 0.11(syst) \tag{4}$$

For $D_s^{(*)}D^{+(*)}$ modes:

$$\frac{Br(B^0 \to D_s^*D^+)}{Br(B^0 \to\ D_s^+D^-)} = 0.9 \pm 0.2(stat) \pm 0.1(syst) \tag{5}$$

$$\frac{Br(B^0 \to D_sD^{+*})}{Br(B^0 \to\ D_s^+D^-)} = 1.5 \pm 0.4(stat) \pm 0.1(syst) \tag{6}$$

$$\frac{Br(B^0 \to D_s^*D^{+*})}{Br(B^0 \to\ D_s^+D^-)} = 2.6 \pm 0.5(stat) \pm 0.2(syst) \tag{7}$$

The error on $B^0 \to\ D_s^+D^-$measurement is dominated by $D_s \to \phi\pi$ branching fraction error. $B^0 \to\ D_s^{+(*)}D^{-(*)}$modes do not contain branching error because all the branching fractions cancel out in the calculations.

III. BLESSED NUMBERS

	Value	
B	$L_{xy}/\sigma(L_{xy})$	> 16
B	$d0$	< 0.0065 cm
B	$\chi^2_{r\phi}$	< 14
D^+	$L_{xy}/\sigma(L_{xy})$	> 15
D^+	$L_{xy}^{\leftarrow B}$	> 0.015 cm
D^+	$\chi^2_{r\phi}$	< 10
Track	$MinP_T$	$> 0.35 GeV/c$

TABLE I: Optimized cuts for $B^0 \to\ D^- 3\pi$

Particle	Cut	$B_s \to D_s 3\pi(\phi\pi)$	$B_s \to D_s 3\pi(K^* K)$	$B_s \to D_s 3\pi(\pi\pi\pi)$
B	$\frac{L_{xy}}{\sigma(L_{xy})}$	> 15	> 18	> 21
B	$d0$	< 0.006 cm	< 0.005 cm	< 0.0055 cm
B	$\chi^2_{r\phi}$	< 10	< 8	< 10
D_s	$\frac{L_{xy}}{\sigma(L_{xy})}$	> 10	> 15	> 20
D_s	$L_{xy}^{\leftarrow B}$	> -0.01 cm	> 0.01 cm	> 0.015 cm
D_s	$\chi^2_{r\phi}$	< 10	< 10	< 10
ϕ	M	$[1.010, 1.029]$		
K^*	M		$[0.84, 0.94]$	
Track	$MinP_T$	$> 0.35 GeV/c$	$> 0.35 GeV/c$	$> 0.48 GeV/c$

TABLE II: Optimized cuts for $B_s^0 \to\ D_s^+ 3\pi, D_s \to \phi\pi$, $B_s^0 \to\ D_s^+ 3\pi, D_s \to K^* K$ and $B_s^0 \to\ D_s^+ 3\pi, D_s \to \pi\pi\pi$

$B_0 \to$	$D^+ 3\pi$	$D_s D^+(\phi\pi)$	$D_s D^+(K^* K)$	$D_s D^+(3\pi)$
Eff ($\times 10^{-3}$)	0.264 ± 0.002	0.409 ± 0.003	0.250 ± 0.002	0.323 ± 0.003
Yield	3331 ± 76	185 ± 16	132 ± 14	91 ± 13

TABLE III: Efficiencies and data yields for $B^0 \to\ D_s^+ D^-$modes

$B_0 \to$	$D_s D^+(\phi\pi)$	$D_s^* D^+$	$D_s D^{+*}$	$D_s^* D^{+*}$
Eff ($\times 10^{-3}$)	0.424 ± 0.011	0.396 ± 0.010	0.113 ± 0.005	0.114 ± 0.003
Yield	185 ± 16	158 ± 34	75 ± 22	133 ± 25

TABLE IV: Efficiencies and data yields for $B^0 \to\ D_s^{+(*)} D^{-(*)}$modes

Effect	Syst. Uncertainty [%]
BP_T spectrum	$\pm3.0\%$
$B^0 \to D^- 3\pi$ composition	$\pm2.5\%$
$D_s \to \pi\pi\pi$ composition	$\pm3.0\%$
$B^0 \to D^+ 3\pi$ Fit	$\pm1.3\%$
$B^0 \to D_s D^+(\phi\pi)$ Fit	$\pm2.6\%$
$B^0 \to D_s D^+(K^* K)$ Fit	$\pm4.0\%$
$B^0 \to D_s D^+(\pi\pi\pi)$ Fit	$\pm4.0\%$
$B^0 \to D^+ 3\pi$ Cuts	$\pm2.0\%$
$B^0 \to D_s D^+(\phi\pi)$ Cuts	$\pm4.0\%$
$B^0 \to D_s D^+(K^* K)$ Cuts	$\pm4.0\%$
$B^0 \to D_s D^+(\pi\pi\pi)$ Cuts	$\pm4.0\%$

TABLE V: Table of systematic errors for $B^0 \to D_s^+ D^-$

	$B^0 \to D_s^* D^+$	$B^0 \to D_s D^{+*}$	$B^0 \to D_s^* D^{+*}$
Fit Syst	$\pm8.0\%$	$\pm3.0\%$	$\pm4.0\%$
D_s^* Composition	$\pm2.5\%$		$\pm2.5\%$
Cut Syst	$\pm4.0\%$	$\pm4.0\%$	$\pm4.0\%$

TABLE VI: Table of systematic errors for $B^0 \to D_s^{+(*)} D^{-(*)}$

Channel	Branching (PDG 2005)
$\Gamma(\phi\pi^+, \phi \to K^+K^-)/\Gamma_{total}$	0.018 ± 0.004
$\Gamma(K^+\bar{K}^*(892)^0, \bar{K}_0^* \to K^-\pi^+/\Gamma(\phi\pi^+, \phi \to K^+K^-)$ [1]	1.25 ± 0.12
$\Gamma(\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+, \phi \to K^+K^-)$	0.565 ± 0.071

TABLE VII: Branching fractions and ratios used in calculations

IV. BLESSED PICTURES

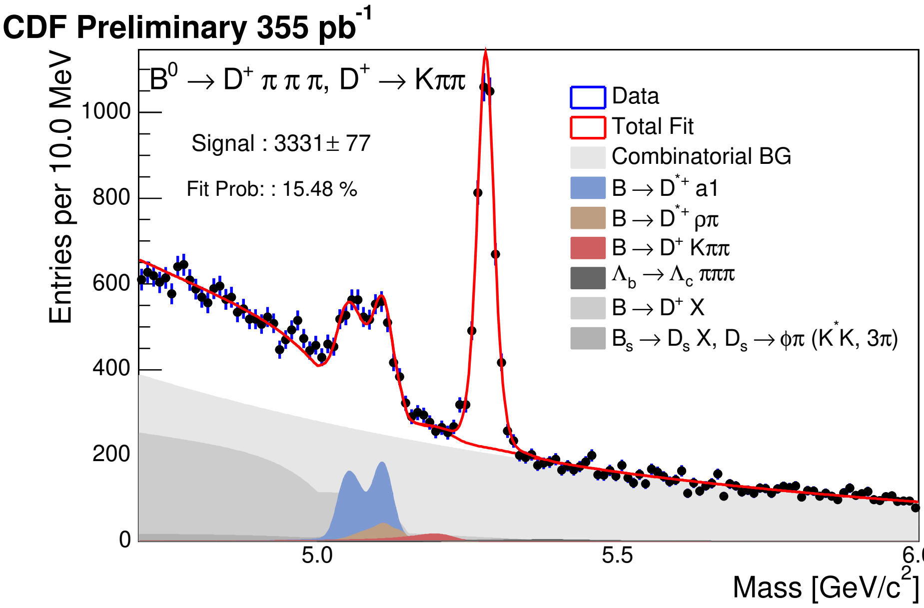

FIG. 1: $B^0 \rightarrow \ D^- 3\pi$ data fit

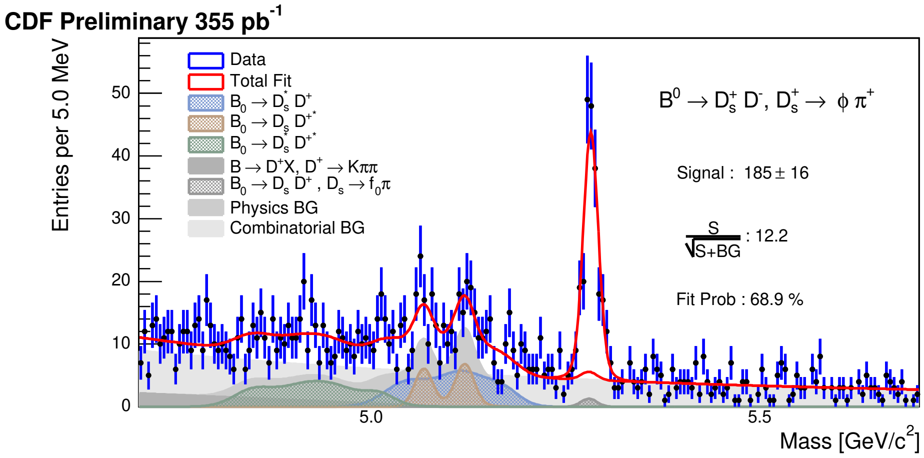

FIG. 2: $B^0 \rightarrow \ D_s^+ D^-, D_s^+ \rightarrow \phi\pi$ data fit

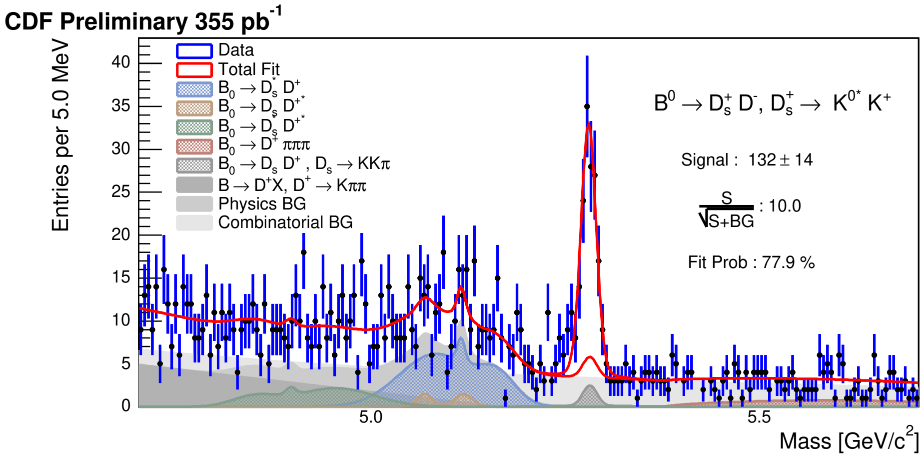

FIG. 3: $B^0 \to D_s^+ D^-, D_s^+ \to K^* K$ data fit

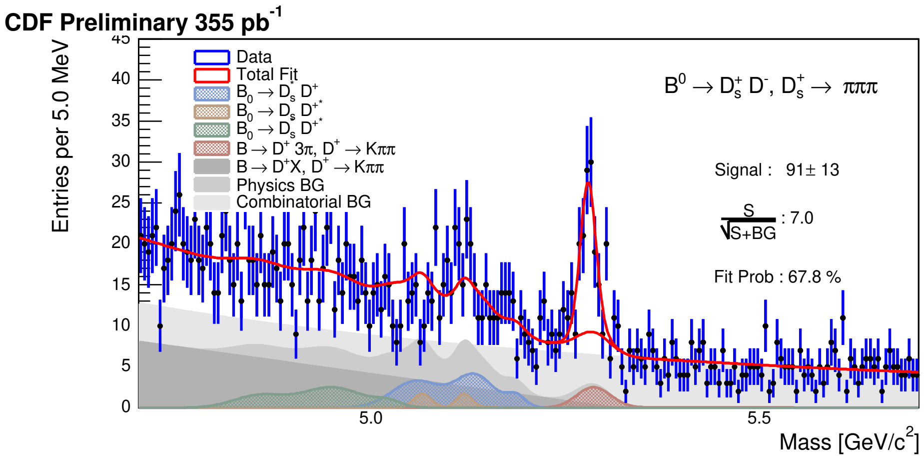

FIG. 4: $B^0 \to D_s^+ D^-, D_s^+ \to \pi\pi\pi$ data fit

[1] CDF note 7495 Measuring of Br($B^0 \to D_s^+ D^-$)/Br($B^0 \to D^- 3\pi$) with $243pb^{-1}$.
http://www-cdf.fnal.gov/physics/new/bottom/050310.blessed-dsd/
[2] CDF note 7815 Measuring of Br($B_s^0 \to D_s^+ 3\pi$)/Br($B^0 \to D^- 3\pi$) with $243pb^{-1}$.
http://www-cdf.fnal.gov/physics/new/bottom/051019.blessed-bsds3pi/
[3] M. Bishai *et. al*
CDF Note 6285, "The Measurement of the b-hadron Inclusive Cross-section in CDF Run II using $b \to J/\psi X$".
[4] C. Peterson *et al.*, Phys. Rev. **D27** (1983) 105.
[5] H.W.Zhao "Study of B Decays into the Final State $D^{(*)}\pi\pi\pi$ at BaBar" hep-ex/0409055
[6] S. Eidelman *et al.*, Physics Letters **B592**, 1-1110 (2004).
[7] S. Eidelman et al., Phys. Lett. B 592, 1 (2004) and 2005 partial update for the 2006 edition available on the PDG WWW pages (URL: http://pdg.lbl.gov/)
[8] (Frabetti et al., FNAL E687 Collab) PL B351 591, Dialitz fit, 701 evts
[9] B. Aubert et al. (Babar Collaboration) " Measurement of $D_s^+ \to \phi\pi$ Branching fraction " Phys.Rev. D71 (2005) 091104